US DOD developing Fuel Cells to power Soldier wearables to Military Vehicles and Submarines to Military Bases

A fuel cell is a device that generates electricity by a chemical reaction. It converts hydrogen and oxygen into water, and in the process also creates electricity. Fuel cells provide many advantages, they are environment friendly as they don't produce pollutants or greenhouse gasses, significantly improving our environment, high energy efficiency (can be close to 80% where they generate both heat and electricity), scalable providing power from milliwatts to megawatts, and complementary i.e. readily be combined with other energy technologies, such as batteries, wind turbines, solar panels, and super-capacitors. There are many types of fuel cells, and each can operate in a clean manner using different fuels including hydrogen, natural gas, methanol, ethanol, biogas.

Fuel cells can extend the operating range and mission of military systems by reducing the dependence on carbon-based fuel sources. They also save energy and reduce the operating costs associated with dependence on foreign oil. "As the U.S. moves to reduce its dependence on foreign oil and become more energy efficient, this technology may well define the future of power and energy for the war fighter," writes ONR.

According to US Military, the reductions in the Department's need for energy can improve warfighting capabilities, such as increased range, better endurance, longer time on station, and reduced requirements for resupply. Improved energy performance also can reduce the risk and effects of attacks on supply lines and enable tactical and operational superiority.

While boosting the military energy readiness by actively promoting low-and no-carbon energy alternatives, the Defense Department is also working to reduce its use of fossil fuels and the resulting greenhouse gases being produced. Another driver behind the American military's move to clean sources of energy is climate change – a threat that military leaders continue to warn policy makers is very real and will impact the military, whether it's responding to natural disasters or responding to conflicts caused by scarce resources.

General Motors has revealed a futuristic-looking hydrogen-powered self-driving army truck. This concept vehicle is essentially a giant self-driving platform that can hold any kind of vehicle body – or even just cargo. Something like this could be useful in disaster zones or in conflicts, the automaker said.

GM has been working on hydrogen fuel cell projects with the military for many years. Earlier this year, the U.S. military began testing a hydrogen-powered GM pickup called the ZH2 . And last year, the Navy began testing a GM-produced hydrogen-powered unmanned submarine.

General Motors Co. and the U.S. Army have developed the Chevrolet Colorado ZH2, an off-road designed fuel-cell electric vehicle the Army will test next year as it considers the viability of using hydrogen-powered vehicles in military use. Specifically, the Army intends to test the Colorado ZH2 fuel cells for quiet, silent watch operation; reduced acoustic and thermal signatures; high torque; low fuel consumption and water by-product for use in the field. GM is also applying that hydrogen fuel cell technology for US Navy unmanned undersea vehicles through a project with the ONR and is exploring a variety of aerospace applications.

Hydrogen power is particularly well-suited for military use, according to GM, because fuel cells produce very little heat. That makes them harder for enemies to detect. Additionally,

hydrogen can be produced in the field from a number of different sources, which means that fuel for the vehicles won’t always have to be transported to the vehicles.

The ONR under the Fuel cells program is exploring improved power generation capabilities within the critical weight and volume constraints of future systems that are designed for increased capability and agility, including all electric naval ships, unmanned (air, surface, subsurface, ground) vehicles, aircraft auxiliary power units and man-portable power applications.

“Fuel cells offer a highly efficient and fuel flexible technology that cleanly produces power and heat with low or zero emissions. Using renewably produced fuels such as hydrogen fuel cells can reduce our nation’s dependence on imported oil, leading to a secure energy future for America. With a multitude of end-uses—such as distributed power for backup, primary, and combined heat-and-power systems; automobiles, buses, forklifts and other specialty vehicles; and auxiliary power units and portable electronics—fuel cell applications hold potential to dramatically impact the 21st century clean energy economy,” writes the U.S. Department of Energy (DOE).

Fuel Cells

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (or protons) to move between the two sides of the fuel cell. The reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes.

Fuel cells are classified primarily by the kind of electrolyte

they employ. This classification determines the kind of electro-chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable.

The six fuel cell types are : PEMFC, Proton Exchange Membrane Fuel Cell, DMFC, Direct Methanol Fuel Cell, PAFC, Phosphoric Acid Fuel Cell, AFC, Alkaline Fuel Cell, MCFC, Molten Carbonate Fuel Cell and
SOFC, Solid Oxide Fuel Cell.

Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are “stacked”, or placed in series, to create sufficient voltage to meet an application’s requirements. The energy efficiency of a fuel cell is generally between 40–60%, or up to 85% efficient in cogeneration if waste heat is captured for use.

Emerging Fuel Cell Applications

Unmanned Aerial Vehicles (UAVs)

Unmanned aerial vehicles (UAVs) are typically used for military operations where manned flights would be too risky or difficult. They send back real-time imagery of activities on the ground and are usually powered by batteries that last up to 30 minutes before they need to recharge. Hydrogen fuel cells can increase UAV air time to approximately 8 hours and, after landing, can be refueled in less than 15 minutes. Also, there are no moving parts—meaning the fuel cell-powered UAV requires less maintenance and zero lubricants.

Unmanned Undersea Vehicles (UUVs)

In partnership with General Motors (GM), the Navy's U.S. Naval Research Laboratory is developing a long-endurance unmanned undersea vehicle (UUV). The Navy started using fuel cells instead of batteries in UUVs to allow bigger payloads and longer runtimes. They recently completed an evaluation of a prototype at the Naval Surface Warfare Center in Carderock, Maryland. Because fuel cells are compact, lightweight, and reliable, they have the ability to run for long periods of time and support the Navy's focus on energy technology for vehicles that need more endurance.

Light-Duty Trucks

GM is also working with the U.S. Army to develop a hydrogen fuel cell-powered light-duty utility truck. The ZH2, based on a Chevy Colorado, has a reinforced body with a suspension built for off-road handling. It's also powered by a fuel cell and a battery that's quieter than traditional internal combustion engines and gives off less heat. This will help in situations where the Army wants to reduce sound and thermal signatures. The truck comes with a 50-kilowatt battery—charged by the fuel cell—that can be removed to power other applications. The ZH2 can also keep soldiers hydrated since the only byproduct from the fuel cell is pure water. The Army is in the process of evaluating the truck for potential use in military operations.

Wearable Power Systems

Ideal equipment weight is 30% of a person's body weight, but some soldiers have to carry more than 100 pounds. To lighten the load, the Army is looking into replacing lithium-ion batteries with fuel cells for power generation—decreasing battery weight by 50%. These "wearable power systems" for the dismounted solider can produce 20 watts (W) of continuous output and 35W of peak power. To aid this effort, the U.S. Department of Energy (DOE) is working to drive down the cost

of aluminum hydride—a promising material that can be used for storing hydrogen to utilize in these portable fuel systems.

Scientists at the U.S. Army Research Laboratory observed an unexpected result when combining urine with a newly engineered nano-powder based on aluminum. It instantly releases hydrogen from the urine at much higher rate than with ordinary water. The research team announced earlier this summer that a nano-galvanic aluminum-based powder they were developing produced pure hydrogen when coming into contact with water. The researchers observed a similar reaction when adding their powder to any liquid containing water.

“We have calculated that one kilogram of aluminum powder can produce 220 kilowatts of power in just three minutes,” said Dr. Anit Giri, also an ARL researcher. Making use of urine as fuel source may result in tremendous benefits for Soldiers, officials said.

Fuel cells for soldiers

“Today’s challenge for our dismounted infantry Soldier is basically weight, so we have situations where some Soldiers are carrying in excess of 100 pounds. Ideally you want to be at a thirty percent body weight, so you want to carry like 30 pounds,” Dr. Tony Thampan, a chemical engineer in the Army’s Communications-Electronics Research, Development and Engineering Center, or CERDEC, said. “Before they would just limit the missions, and that takes away capability.”

Thampan modeled, designed, and developed a Soldier wearable power system that can cut a Soldier’s weight burden by up to four times. He did this by using a fuel cell membrane made of Aluminum hydride, or AlH3, which provides a better energy density than the common Li-on battery used today.

“Now that these solutions have increased energy density

systems, you can go out on longer missions and keep the weight manageable," Thampan said.

The wearable power system powers individual Soldier devices or all of a Soldier's ensemble devices – such as worn radios and end user devices – through a power distribution system. It consists of a power unit with an internal starting battery, fuel gauge and fuel cartridges.

The system is flexible and can be worn in a pouch on the side of a Soldier's vest. It has passed government ballistic testing requirements and is rated safe for Soldier's to wear.

SAFCell Inc. Awarded Enhancement Grant from US Army to Produce a 50 Watt Fuel Cell Power Unit

SAFCell and UltraCell have commenced the design and fabrication of a 50 watt, propane-fueled power unit based on the use of SAFCell's proprietary Solid Acid Fuel Cell stacks in UltraCell's world-leading military portable power systems. This first-of- its-kind ultra-light power unit will reduce by half the total battery weight burden on the modern soldier, up to 44 pounds for a three-day mission, enabling them to carry more mission critical equipment and ammunition.

Commenting on the Enhancement award, SAFCell's CEO and President Dr. Calum Chisholm said: "This award enables us to demonstrate the advantage of using our fuel-flexible Solid Acid Fuel Cell technology in UltraCell's ultra-rugged, portable power system design. The portability, fuel-efficiency, and silence of the final unit will make it ideal not only for military use, but for commercial applications as well."

SAFCell announced that it has won a competitive $3 million

award from the U.S. Department of Energy’s Advanced Research Projects Agency-Energy (ARPA-E). SAFCell will use this funding to develop a solid acid electrochemical hydrogen compressor (EHC) that converts ammonia directly into high purity, high pressure hydrogen.

The solid acid EHC unit will enable onsite hydrogen generation and compression from renewable, energy-dense carbon-neutral liquid fuels (CNLF), such as ammonia and bio-methanol. Such one-step hydrogen generation and compression would enable low cost, wide-scale storage and delivery of renewable energy for use in both stationary and transportation sectors.

This award enables us to demonstrate that our fuel-flexible Solid Acid technology can generate hydrogen from any of the commercial fuels that our fuel cell systems run on, and in particular, we can run on renewable fuels like ammonia.

Fuel cell vehicles

FCVs represent a radical departure from vehicles powered by conventional internal combustion engines. Rather than relying on energy from an external source, FCVs could potentially self-generate more than twice the amount of energy of an internal combustion engine – without the noise or emissions. FCVs run on power generated onboard the vehicle through a chemical process using hydrogen fuel and oxygen in the air. FCVs offer a potentially sustainable energy source through the mixture of hydrogen and oxygen, with zero air emissions produced.

GM and U.S. Army to Demonstrate Extreme

Off-Road Hydrogen Fuel Cell Chevrolet Colorado

General Motors and the U.S. Army Tank Automotive Research, Development & Engineering Center (TARDEC) have modified a Chevrolet Colorado midsize pickup truck to run on a commercial hydrogen fuel cell propulsion system and will expose the truck to the extremes of daily military use for 12 months.

“Hydrogen fuel cell technology is important to GM’s advanced propulsion portfolio, and this enables us to put our technology to the test in a vehicle that will face punishing military duty cycles,” said Charlie Freese, executive director of GM’s Global Fuel Cell Engineering activities.

Fuel cell propulsion has very high low-end torque capability useful in off-road environments. It also offers exportable electric power and quiet operation, attractive characteristics to both commercial and military use.

“FCVs are very quiet vehicles, which scouts, special operators and other specialties place a premium,” he said. “What’s more, fuel cells generate water as a by-product, something extremely valuable in austere environments.”

Hydrogen fuel cell propulsion technology helps address two major environmental challenges with automobiles today – petroleum use and carbon dioxide emissions. Fuel cell vehicles can operate on renewable hydrogen from sources like wind and biomass. Water vapor is the only emission.

Navy considering Fuel cells for Unmanned Underwater Vehicles to submarines

ONR and its partners across government, defense and private industry are exploring fuel cell power to expand warfighter

capabilities – whether to reduce the size and weight of man-portable devices or to meet megawatt requirements for shipboard power. A fuel cell vehicle (FCV) uses hydrogen-powered fuel cell propulsion instead of a standard internal combustion engine.

Within the Navy and Marine Corps, ONR has long recognized that greater fuel efficiency can improve the effectiveness of U.S. forces. In the field, FCVs would increase mission endurance and stealth, while reducing logistical burdens and costs.

Currently, two ONR-sponsored FCVs operate at the Marine Corps Base at Camp Pendleton. These vehicles provide instant torque from the start without a drop of oil, only emitting water vapor. FCVs require no pistons or cylinders. Because they have no transmission, FCVs relieve drivers of manual shifting. Acceptance of the technology is widening by users who find them fun, clean and “green” to operate.

GM collaborating with Navy for fuel cells in Unmanned Underwater Vehicles

Hydrogen fuel cells convert high-energy hydrogen efficiently into electricity, resulting in vehicles with greater range and endurance than those powered with batteries. Under the ONR’s Innovative Naval Prototype program for Large Displacement UUVs (LDUUV), energy is a core technology in the Navy’s goals for vehicles with more than 60 days endurance. The Navy plans to test the LDUUV in the open sea this year and could field a first squadron of the robotic submarines by 2020.

The Naval Research Laboratory recently concluded an evaluation of a prototype unmanned underwater vehicle equipped with a GM fuel cell at the heart of the vehicle powertrain.

“Our in-water experiments with an integrated prototype show

that fuel cells can be game changers for autonomous underwater systems," said Frank Herr, ONR's department head for Ocean Battlespace Sensing. "Reliability, high energy, and cost effectiveness – all brought to us via GM's partnering – are particularly important as Navy looks to use UUVs as force multipliers."

"GM's fuel cells are compact and lightweight, and have high reliability and performance. Lower cost is achievable through volume production. These attributes match the goals of the Navy to develop reliable, affordable systems," claims GM.

In future submarines could be power by Hydrogen Fuel Cells, The advantage of a fuel-cell system aboard submarines is their air independent operation.

Fuel cells for Military bases

The U.S. Army Corps of Engineers is powering stateside installations as well as bases in forward operating locations with fuel cells—electrochemical cells that convert fuel sources into electric currents. The efforts result in money savings, a reduction of the dependence on foreign oil, essentially unlimited power generation and a cleaner environment.

For backup power, installations can connect fuel cells to a grid so the energy sources will kick in during an emergency without a disruption in electrical services. This ensures the continued operation of mission critical resources such as computer rooms, telephone switching equipment, command centers, hospitals and emergency centers.

Nick Josefik, a mechanical engineer at the ERDC-CERL, says that over the years the laboratory has installed more than 200 fuel cells in various sizes. These range from 500-watt models that back up a few computers to 250- to 500-megawatt systems

that can power entire subdivisions, hospitals or industrial buildings. The fuel cell installations are split almost evenly between prime power and backup power use. Through this work, CERL is helping the military meet its goal to reduce energy usage 25 percent by 2015.

Ultra-clean CHP-capable fuel cell power plants

The beauty of fuel cells is that they can also be integrated with other forms of renewable energy generation, to store energy or to produce electricity and heat later. No other distributed energy source can duplicate this kind of flexibility.

Combined heat and power (CHP) is gaining increased recognition as a cost-effective solution for meeting growing energy needs while reducing the environmental impact of power generation. Reliable on-site power generation improves power reliability and energy security, attributes valued at various U.S. military bases with DFC power plants.

Ultra-clean Direct FuelCell® (DFC®) power plants, unlike traditional reciprocating engines and gas turbines, produce virtually no nitrogen oxides (NOx), sulfur oxides (SOx), or particulate emissions (PM). While the average fossil fuel power plant in the USA produces nearly 25 pounds of these emissions per megawatt hour, the DFC fuel cell produces just 0.1 pounds of these emissions.DFC power plants also emit dramatically less carbon dioxide (CO2) than combustion-based power generation, a significant reduction of greenhouse gas emissions, particularly when configured for CHP applications.

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